Understanding the coupling of surface, boundary layer, cloud and radiative processes in the Global Water and Energy Cycle

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Project hypothesis is that quantifying and evaluating the coupling of land-surface, boundary-layer, cloud and radiative processes will lead to improved simulation of the 'Global Energy and Water Cycle' in climate and weather forecast models.

Objectives & deliverables:

- Quantify/evaluate the links between the soil moisture, the surface heat fluxes, mean cloud-base and the short-wave and long-wave cloud forcing at the surface and the model dynamics in the GMAO GEOS-5 analysis/ forecast model and its successors.
- Compare GEOS-5 with ERA reanalyses.
- Explore the controls on the amplitude of the diurnal cycle of 2-m temperature and relative humidity; and the amplitude and depth of nocturnal BL.
- Use idealized models to study the coupling between transpiration and CO_2 fluxes, the cloud field and the BL equilibrium, on timescales longer than diurnal.

Background references

- Betts, A. K., 2004: Understanding Hydrometeorology using global models. *Bull. Amer. Meteorol. Soc.*, **85**, 1673-1688.
- Betts, A. K and P. Viterbo, 2005: Land-surface, boundary layer and cloud-field coupling over the south-western Amazon in ERA-40. *J. Geophys. Res.*, **110**, D14108, doi:10.1029/2004JD005702.
- Betts, A. K., B. Helliker and J. Berry, 2004, Coupling between CO_2, water vapor, temperature and radon and their fluxes in an idealized equilibrium boundary layer over land. *J. Geophys. Res.*, 109, D18103, doi:10.1029/2003JD004420.
- Betts, A. K, J.H., Ball, P. Viterbo, A. Dai and J. A. Marengo, 2005: Hydrometeorology of the Amazon in ERA-40. *J. Hydrometeorology*. (In press)
- Betts, A.K., 2005: Radiative scaling of the nocturnal boundary layer. J. Geophys. Res., (submitted)

Technical approach and/or methods

What does a model show about the coupling of processes/observables?

Is it right?

Are the observables coupled in the same way in data?

Is the river basin-scale hydrology realistic?

•Key near-surface observables:

– BL quantities: RH, LCL, DTR, (NBL) ΔT_N, ΔCO_{2N}

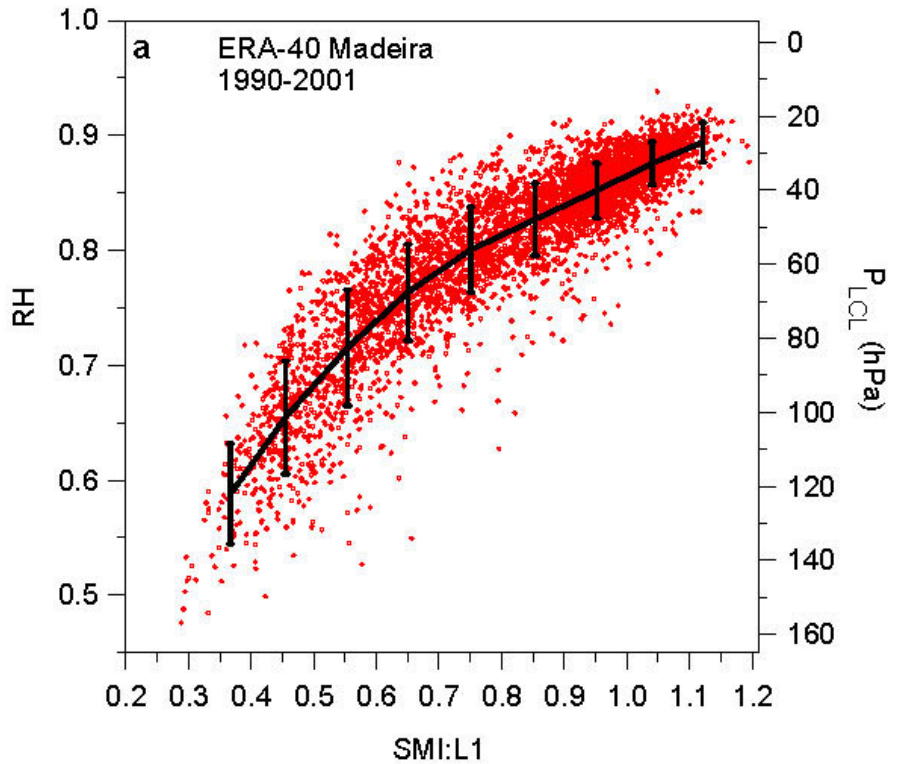
– α_{cloud} : Cloud impact on surface SW

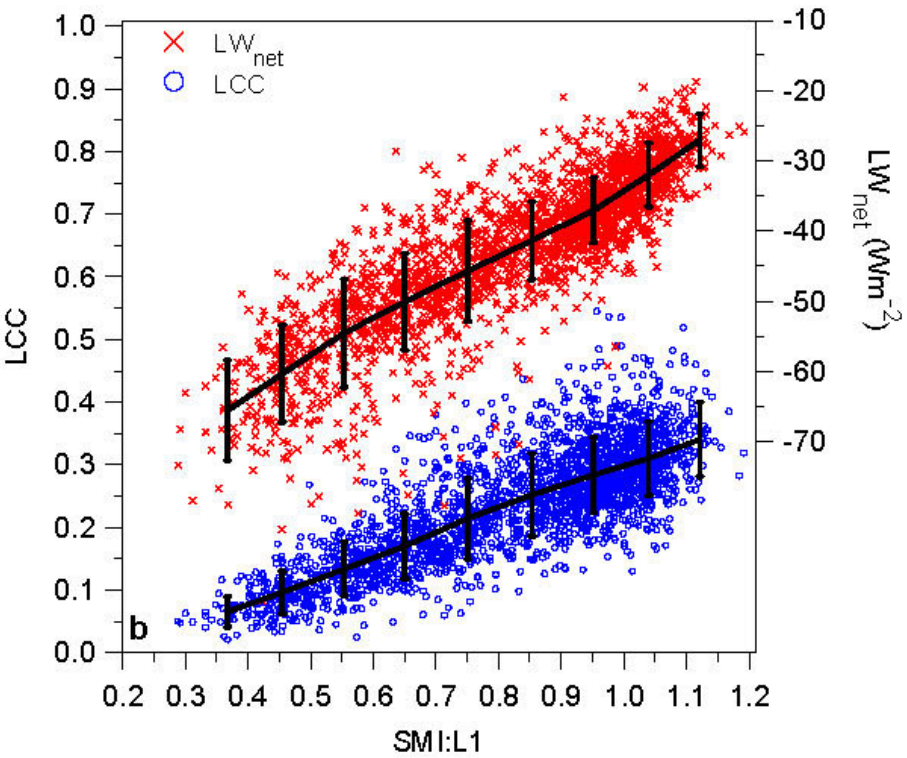
- LW_{net}: linked to LCL, cloud, diurnal cycle and NBL

Following examples show

- ERA40 examples of coupling of physical processes
- ERA40 comparison with FLUXNET data

ERA40: Surface 'control'

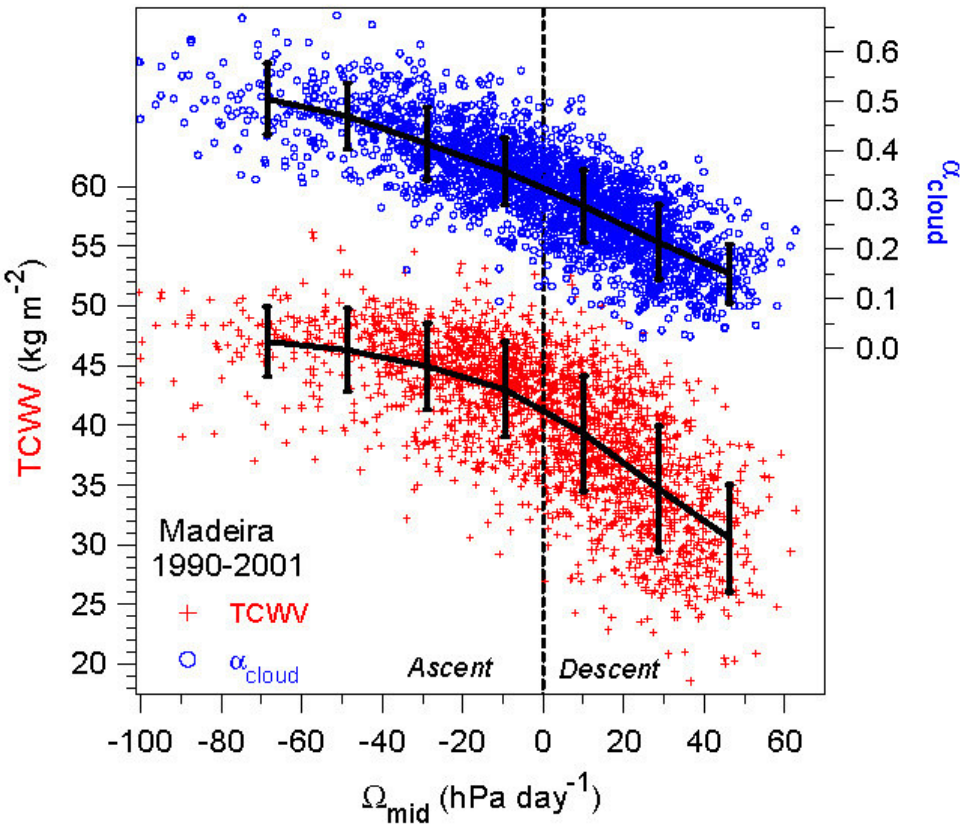


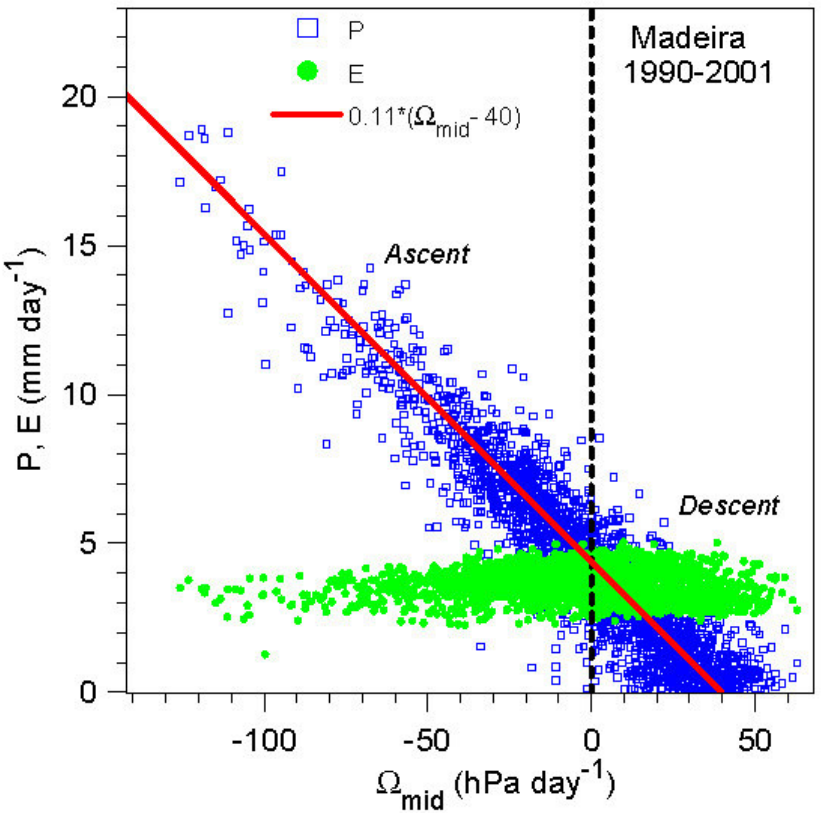


- Madeira river, SW Amazon [daily means]
- Soil water ⟶ LCL, LCC [low cloud] and LW_{net}

[Betts and Viterbo, 2005]

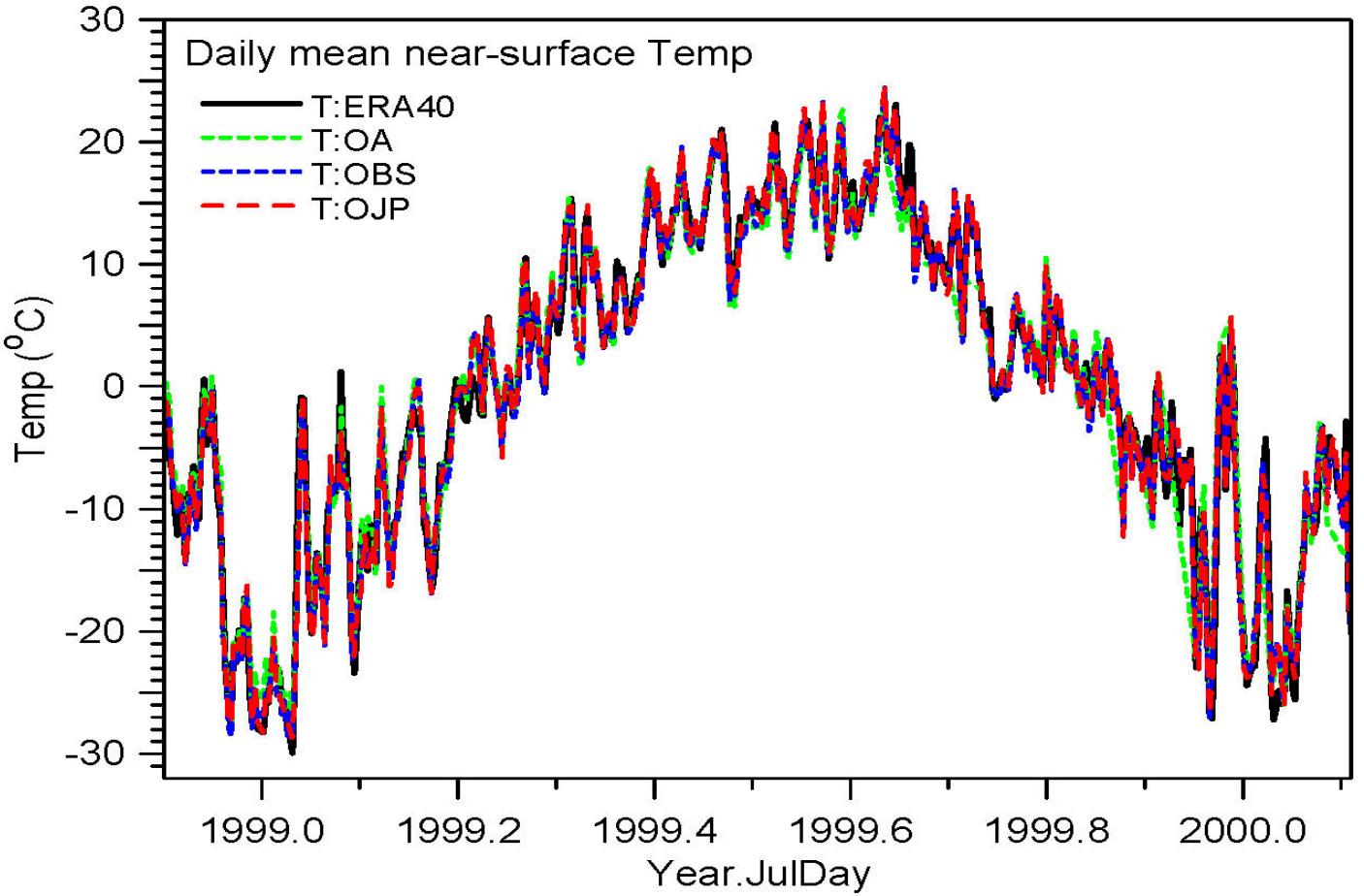
ERA-40 dynamic link (mid-level omega)





- Ω_{mid} → Cloud albedo, TCWV and Precipitation

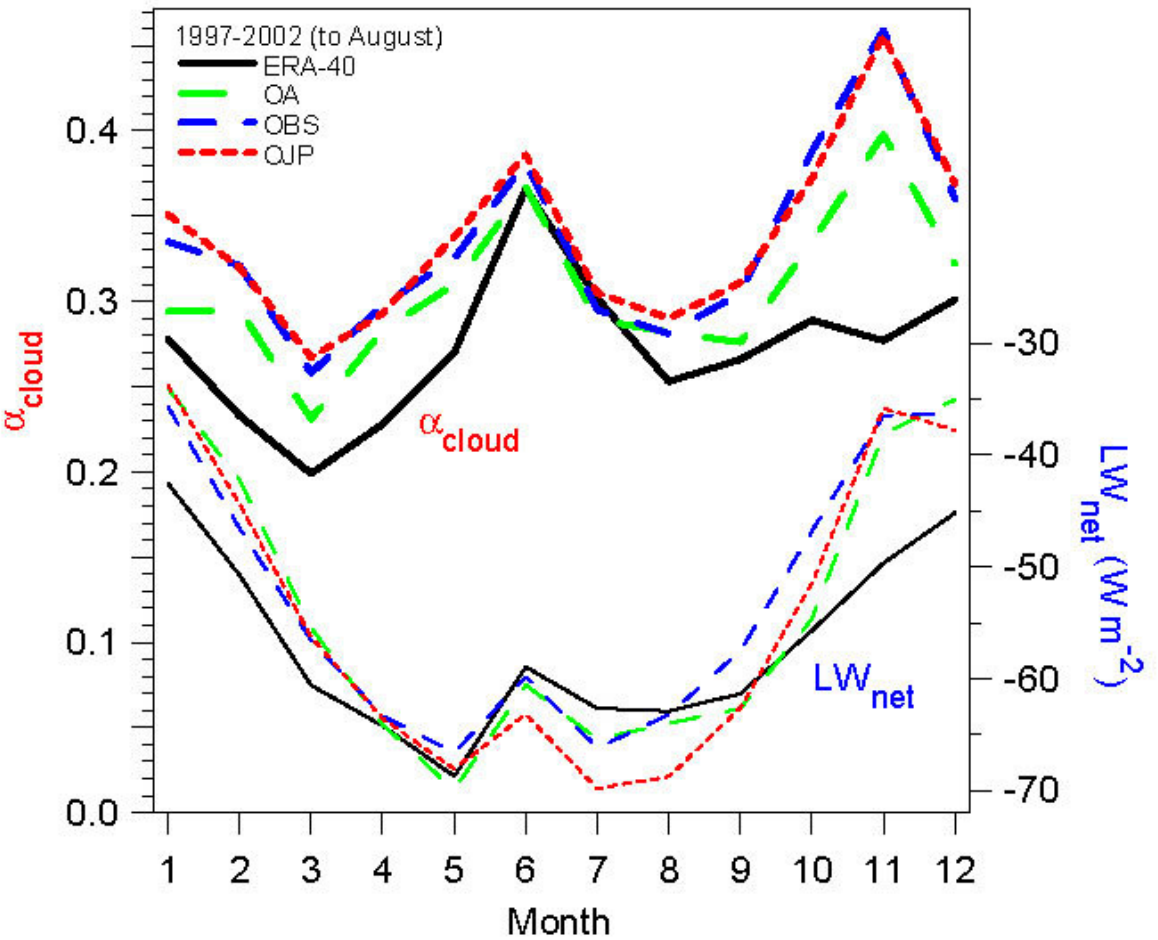
Global model improvement [ERA40]



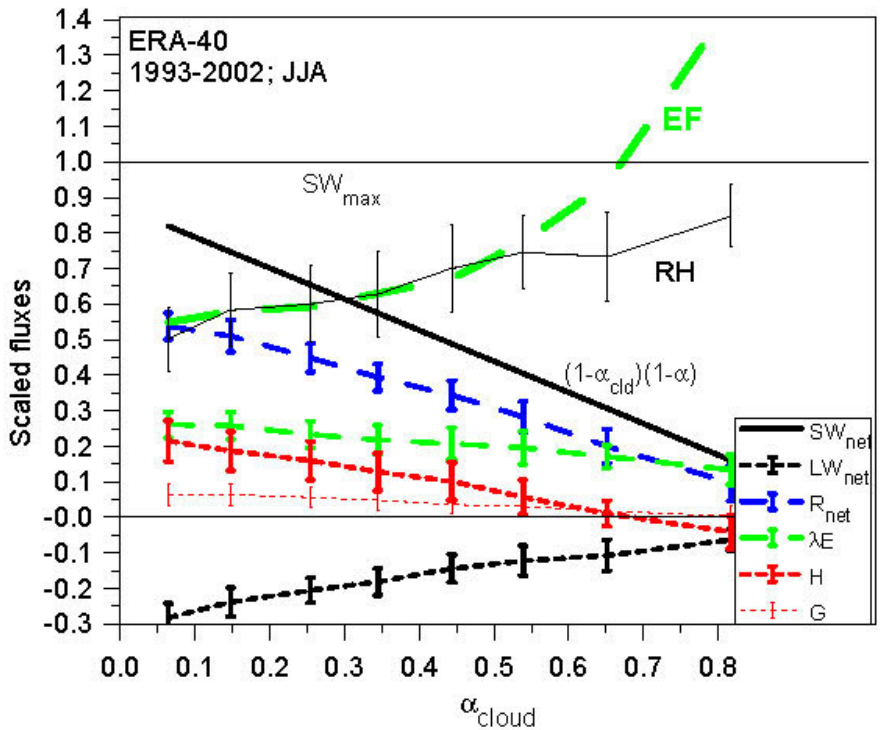
- ERA40 land-surface model developed from BOREAS
- Reanalysis T bias of now small in all seasons for this location
- BERMS inter-site variability of daily mean T is small

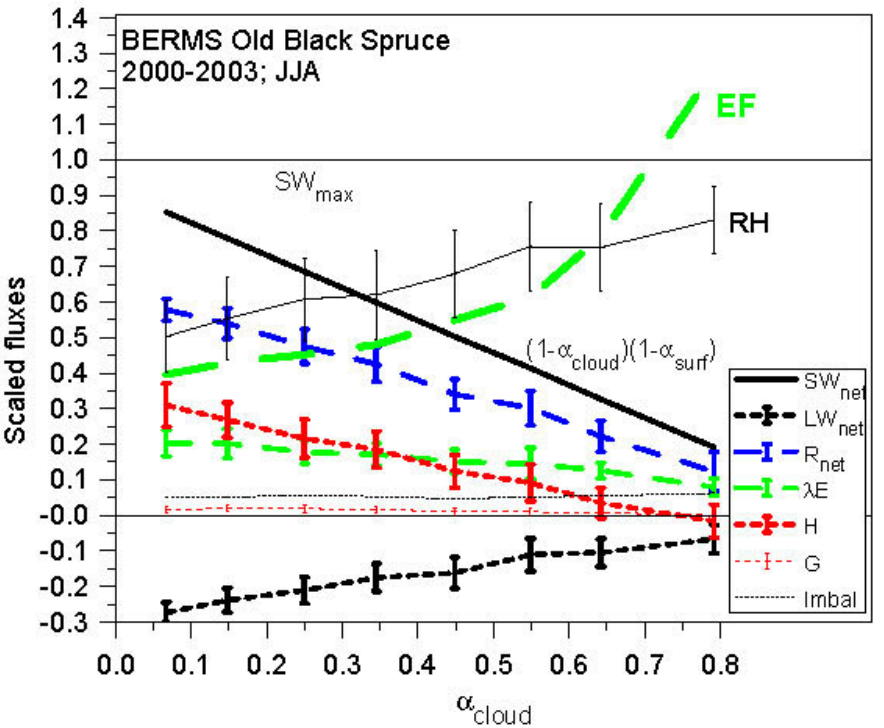
Cloud albedo and LW_{net} comparison with BERMS

- ERA-40 has low α_{cloud} except summer
- ERA-40 has LW_{net} bias in winter?



How do fluxes depend on cloud cover?





- Bin daily data by α_{cloud}
- Quasi-linear variation
- Evaporation varies less than other fluxes

Data set needs:

- Point data from GEOS model/analyses and FLUXNET/CEOP sites
- Basin-scale data from GEOS model
- NEWS estimates of surface and TOA radiative fluxes; or preferably surface and TOA cloud forcing

Project outputs

- Diagnostics of GEOS model characteristics and errors: diurnal, seasonal, with respect to data and ERA40, stratified by physical processes [soil moisture; cloud forcing, ML depth, omega]
- Conceptual and idealized models for land-surface-atmosphere coupling
- Some links to the carbon cycle
- Data volume : a few Gbytes

Potential collaborations (with NSIT, other NEWS projects, etc.) **:**

- Bosilovich and GEOS-5/MERRA physics development team [Rodell, Reichle]
- Koster: land-surface coupling
- Roads: WEBS; CEOP
- Peters-Lidard: LDAS/LIS
- Denning: Vegetation modeling
- Wielicki: radiative forcing

Important outside linkages/resources

- ECMWF reanalyses and model development
- FLUXNET data

Expected contribution to the NEWS objective:

- Global model development for NEWS
- Improved global water and energy cycle [climate studies/applications]

Issues, needs, and concerns

- NEWS needs one validated modeling system to produce 'products'

  - How will a next generation data assimilation and global modeling be developed and managed? [and coordinated with NCEP]

  - How can NSIT provide or influence 'science management' of NASA's model development?

  - [Will NASA commit sufficient resources and people for the 15 years needed? Model development needs stable funding]